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ABSTRACT

This study was intended to determine whether sex-linked mathematics achievement and contextual differences persist into the university years. A random sample of 150 first-year mathematics students enrolled at a midwestern university was identified. A common 30-item calculus readiness test and a 37-item questionnaire, dealing with students' perceptions of the context of mathematics learning, were administered to all students present on the testing day. One hundred examinees returned the questionnaire, and 131 completed the calculus readiness test. Of the 100 questionnaire respondents, 91 had taken the test. Data on these 91 subjects were used in subsequent analyses where data for both instruments were involved. When high school algebra grade was controlled, males scored significantly higher than did females on the calculus test. However, a multivariate analysis of variance of the seven components of the test produced a significant sex effect and univariate differences in favor of males were found for geometry, inequalities, and conceptual problems. The sex variable, coded as a dummy effect, did not enter the regression equation. Algebra study and hours of mathematics homework accounted for 53.5% of the variance in the test grades. Five data tables are included. (TJH)

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Sex Differences in Mathematics Performance and Perceptions of University Students

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Abstract

In our previous studies of school children we have reported consistent sex differences in problem-solving components of the mathematics tests. Also, mathematics achievement has been found to be related to its functional utility. This study was intended to determine whether in the university population sex-linked achievement and contextual differences would persist. A random sample of 150 first-year-mathematics students was identified. A common Calculus Readiness (CR) test was administered to all students present on the testing day by the course instructors. Of the sample, 100 returned the questionnaire dealing with students' perceptions of the context of mathematics learning and 131 wrote the CR.

When controlled for the high school algebra grade, males were significantly higher than females on the CR. However, the Manova analysis of the seven components of the CR produced a significant Sex effect and univariate differences in favor of males were found on Geometry, Inequalities, and Conceptual Problems. Sex variable, coded as a dummy effect, did not enter the regression equation; and algebra and hours of mathematics homework accounted for 53.5% of the variance in the CR grades. Interesting differences and similarities in contextual perceptions of males and females were found which also seem to suggest interesting theoretical implications.

Sex Differences in Mathematics Performance and Perceptions of University Students

Over the years, many psychologists have been trying to explain sex differences in achievement and ability in mathematics. Usually, research results show that mathematics is a male dominated field and that males generally outperform females. Many theories have been formulated to explain this phenomenon. This review discusses some of these theories and presents pertinent research evidence on sex-related differences in mathematics.

The literature seems to indicate that females have not been given as much attention as males during instruction and are often expected to perform poorly in mathematics. There are many social pressures on females to not achieve well in mathematics. In Sudan, for example, parents send their daughters to elementary school, but do not wish them to continue on to high school and beyond; whereas the boys are expected to pursue their education (Pollitt, Searl, & Sheikh, 1987). In our North American society females are not expected to achieve well in mathematical fields (Maccoby & Jacklin, 1974); this increases the pressure on them should they attempt to do otherwise. Although research has shown in the past that males do usually develop higher mathematical ability and achieve higher in mathematics than females (Backman, 1972; Ernest, 1976; Fennema, 1974; Fox, 1976; Fox, Brody, & Tobin, 1980; Garai & Scheinfeld, 1968; Keating, 1974; National Assessment of Educational Progress, 1975; Wilson, 1972), this

is not always the case -- nor does this generalization apply to all grade levels and to all components of mathematics (Randhawa, 1988; Randhawa & Hunt, 1987; Randhawa & Randhawa, 1989a, 1989b). Because females are not given as much instructional assistance (Leder, 1987) and face lower expectations they must work doubly hard against these stereotypes to achieve as well as males in mathematics.

Students' attitude towards mathematics seems to play a key role in how well they will do. Boys seem to have a more positive attitude towards mathematics than girls, especially in high school. Also, high confidence boys interact with their teachers at higher cognitive levels than high confidence girls (Fennema,1983). Males tend to be much more independent than females (Maccoby & Jacklin, 1974). They are not afraid to talk and ask questions in the classroom. Often, girls feel too shy to ask questions and do not want to display a lack of understanding (Stake & Katz, 1982). Girls are capable of sustained personal efforts as well as perseverance (Maccoby & Jacklin, 1974). In addition to benefiting from the information received in the classroom, females get more out of a self study method of teaching (Pollitt, Searl, & Sheikh, 1987). Boys, on the other hand, are very comfortable in the classroom. Because teaching mathematics in our schools is almost always in the form of lecture, demonstration, drill, and seat work (Ethington & Wolfle, 1984), this context and format might be one possible explanation of sex differences.

Teachers' attitudes towards students also seem to bear on

sex differences in mathematics. The majority of teachers seem to interact more with male students than with female students. Teachers initiate more contact with boys than with girls. Boys receive more discipline as well as praise (Maccoby & Jacklin, 1974). Teachers also accept mistakes more from boys than from girls and criticize girls more for their academic work. Finally, teachers interact more with high achieving boys than with high achieving girls (Fennema, 1983). An examination of these data suggests that boys get more attention as well as help in the classroom. Therefore, girls must again work harder to keep up and, more often than boys, must try and figure out things on their own.

Another interesting phenomenon is that girls achieve better than boys on reading comprehension (Randhawa & Hunt, 1987). As a result of this, one would think that girls should outperform boys on story problems in mathematics; this is not the case. Boys seem to edge females on story problems while females edge boys in computation questions. Also, girls who excel in reading do worse on story problems than other girls and boys (Marshall, 1984).

Girls seem to have mastered the rules and laws of mathematics. Therefore, they are rewarded for their rule governed behavior. Because of this reason, girls may do better on such things as computations because of the rules and laws applied to them. Boys, on the other hand, have a more carefree attitude when it comes to mathematics. This open approach may explain their success on story problems

(Marshall, 1984).

An interesting theory of Autonomous Learning Behavior (ALB) has been proposed by Fennema and Peterson (1985). According to this theory, people have internal motivational beliefs that determine a person's ALB. Both of these are influenced by different external or social influences. Because these different influences and individual internal motivational beliefs affect a person's ALB, these factors can help to explain sex-related differences in mathematics. This theory seems to have some parallelism with Bandura's(1977; 1982) self-efficacy theory of behavioral change which provides some explanatory validity for individual and group differences. There are certain cognitive and socio-contextual characteristics which differentiate females and males. For example, females appear to be very dependent between the ages of 3-14 (Kagan & Moss, 1962). Males are much more independent than females (Maccoby & Jacklin, 1974). Grieb and Easley (1984) stated that young girls and women demonstrate specific patterns of behavior, such as dependence on memorization. Finally, females tend to display learned helplessness much more than males (Dweck & Repucci, 1973; Deaux, 1976). These different characteristics may represent some of the differences in internal motivational beliefs of males and females.

Furthermore, there is some evidence that external influences may affect a person's ALB. As previously discussed, society views females' participation in mathematics

much differently than males' and teachers treat female students differently. Also, females do not learn as well as males in a classroom environment (Fennema, 1983). Therefore, the Autonomous Learning Behavior theory seems to offer a viable alternative for explaining sex differences.

The background characteristics of a student may determine how he or she achieves in mathematics. For example, the mother's and father's education play a key role, as do sex, spatial visualization, ability, perceptual ability, attitude, and exposure (Ethington & Wolfle, 1984). Children of parents with higher levels of education would be expected to achieve higher than children whose parents have little or no education. Children who have been immersed in mathematics at an early age would also be expected to achieve better as would children with a positive attitude, which at a later age, tends to be mostly boys. All of these background factors are thought to affect a child's learning and may partially explain why the child performs as he or she does in mathematics.

Another relevant idea is that researchers should study the errors that children make in mathematics. Possibly these errors may assist in revealing why sex differences occur. The distribution of boys' and girls' errors differ (Marshall, 1983). Girls' errors generally are more likely than boys' to be due to misuse of spatial information, use of irrelevant rules, incorrect operation, negative transfer, and word association. Boys' errors are usually errors of perseverance and formula interference. Both males and females make

language errors, but these are not the same (Marshall, 1983). So, by studying the errors of males and females, it is hoped that researchers can determine why they make these different mistakes and thereby offer effective intervention strategies. If we can pinpoint the origins of student errors, then more time and attention may be focused on different areas of difficulty and variant or new teaching methods may be developed that will be of increased benefit to the students.

In conclusion, the field of sex differences in mathematics is ripe for ingenious theoretical and empirical work. To say that sex differences in mathematics occur because of one specific reason would be very misleading. The cause of these sex-based occurrences may be a result of a combination of reasons incorporating bits and pieces of information from a variety of theories. The problem with this approach is that although males and females may have certain characteristics that apply to each sex, each individual is different. Each might have a pattern of thinking different from another of the some sex. To narrow down the explanation of why such differences occur would be to exclude certain cases that may be the exception to the rule. To include everyone, we must look at all the different theories, take information out of them that applies, and formulate a new and more comprehensive explanation as to why sex differences occur. This may mean adding pieces to include the exceptions to the rule. In order to find a comprehensive explanation more research and thinking is required. It is in this vain that the present research is

directed.

The present study was concerned with high school graduates who were enrolled in a first-year mathematics course at a university and, attempted to determine whether sex differences found on standardized achievement tests in grade 10 persisted in this population on a test of mathematical concepts and abilities prerequisite to the study of calculus. Also, this study is intended to determine whether the global achievement sex difference is pervasive in the components of this test. Furthermore, it addressed the issue of contextual saliency of the learning environment of the participants.

Specifically, the present research was aimed at addressing the following questions:

1. Are the means of males and females, enrolled in the first year university mathematics courses, on the total Calculus Readiness test (CR) scores significantly different?

2. Are the profiles of means of males and females, enrolled in the first year university mathematics courses, on the CR component scores significantly different?

3. What is the best predictor set of CR total scores for the sample?

4. What non-cognitive variables as a set predict optimally the total CR scores of the sample?

5. How do the first year university males and females perceive the context of their high school mathematics learning experiences?

Method

Subjects

A sample of 150 first year students was selected. These students were selected from those who were enrolled in mathematics courses intended for different programs at a mid-western university. The selection procedure involved identifying randomly one of the pages of the lists of names of students enrolled in various classes. From this page one number was selected randomly and then every fifteenth name was identified starting from the first identified student. This process was continued until students from all the pages were identified.

Instruments

Calculus Readiness Test (CR). This is a 30-item test entailing seven parts: 1) Geometry consisting of three items; 2) Inequalities comprising of two items; 3) Algebra containing five items; 4) Exponential and Logarithm including seven items; 5) Functions representing three items; 6) Trigonometry having five items; and 7) Conceptual Problems spanning five items. The Department of Mathematics' instructors of this university have prepared various forms of this test so as to ascertain the level of readiness of students taking various first year mathematics courses. A form of the test is usually administered in September of each academic year. An extensive amount of data on the reliability and validity of this test are already available. The average KR-20 reliability of this test for the last three administrations is .91. The test is also shown to be a reasonable predictor of the final grade in

the first year mathematics courses.

Survey Form. The investigators prepared a 37-item questionnaire. It consists of three parts. Part A elicits demographic information through five items. The subjects are asked to indicate their sex, and the occupation and education of their father and mother. Part B consists of twenty items requiring information on learning-related circumstances of the respondents. In this part subjects are asked to indicate how well they did in their grade 12 algebra, how many hours per week they spent on mathematics homework, how many hours per week they watched T.V., and who gave them help in doing homework in mathematics. The learning styles of students and teaching styles of their high school teachers were also assessed. Part C consists of twelve items. It basically assesses students' likes and dislikes and their perceptions of others' expectations. Eight of the twelve items in this part consist of 5-point Likert scales.

Procedure

The CR was administered by the mathematics instructors to all those students who were present on the day of the administration. The investigators were given access to these data by the Mathematics Department. From the total data set the investigators created a subfile of the item level responses of those 150 subjects who were randomly selected for the present study and who had written the CR.

The survey form along with the an optical scan answer sheet and a return envelope were included in an envelope for

the sample. Each subject was assigned a numerical identification code and this was included on the answer sheet. The packages for each mathematics class were given to the respective instructors for handing out to the sampled subjects. The subjects were instructed to respond to the survey form and to return the survey form and the answer sheet in the provided envelope directly to the researchers through the university mail system. The instructors reminded the students in their classes and encouraged them to return the survey form package to the researchers at least three times during the first three weeks of October. One hundred completed questionnaires, of the 150 sent out, were returned.

For these 100 subjects grade 12 marks in Algebra (Alg 30), Calculus, and Geometry-Trigonometry (Geo-Trig) were obtained from the university records. However, a substantial number the students in this group had not taken Calculus and/or Geo-Trig. Therefore, only Alg 30 was used in subsequent analyses of the data.

Analysis

Of the 100 respondents who returned the completed questionnaire, 91 had written the CR. The data from these 91 subjects were used in subsequent analyses where data from both instruments were involved.

The total scores of the CR were analyzed in a one-way analysis of covariance (Ancova) with Sex as the independent variable and grade twelve algebra (Alg 30) as a covariate. Furthermore, the seven CR component scores were used as a

dependent variable set in the one-way multivariate Ancova similar to the above analysis.

The total CR score was used as a dependent variable in a step-wise multiple regression analysis (MR). The predictor variables were Alg 30, Sex, SES (created as a weighted sum of four items pertaining to father's and mother's occupation and education), hours of homework, hours of T.V. viewing, whether or not took geometry in high school, whether or not took geo-trig in high school, whether found word problems or straight mathematical computations easier, type of university mathematics course enrolled, whether the enrolled university mathematics course was required in the program, whether high school mathematics teachers used teaching aids, the frequency with which the mathematics teachers related mathematical material to everyday situations, the frequency of mathematics teachers properly motivating the student, the method of teaching preferred, the learning situation most helpful, the perceived difficulty of high school mathematics exams, the frequency of Alg 30 exams, the usefulness of mathematics, the extent of enjoyment of high school mathematics, and perceived sex stereotyping.

Finally, crosstabulations of perceptual responses to the questionnaire items were produced by sex, and the significance of the independence of these was assessed using the chi-square inferential test. All the above analyses were made using the SPSS-X programs.

Results

Sex Differences on CR Total Score

For this analysis usable data were available for 90 subjects (51 males and 39 females). The observed means of males on CR and Alg 30 were respectively 18.4 and 83.5, whereas the corresponding means of the females were 16.1 and 81.1. Since Alg 30 was used as a covariate the adjusted means on Alg 30 for males and females were respectively 18.1 and 16.5. Males' adjusted mean was significantly greater than that of females' [F (1, 87) = 3.67, $p \leq .10$]. The level of significance for all the inferential tests made was set at 0.10. Therefore, in spite of the lower Type I errors observed in many instances, this level of significance is reported throughout.

Sex Differences on CR Component Scores

The observed and adjusted means on the seven component scores of the CR for males and females are given in Table 1. The multivariate analysis of variance results indicated that the profiles of means for males and females were statistically significantly different [F (7, 81) = 2.38, $p \leq .10$]. However, the corresponding univariate Ancova results indicated that males performed better than females ($p \leq .10$) on Geometry, Inequalities, and Conceptual Problems.

Insert Table 1 About here.

Best Predictor Set of CR Scores

In this regression, categorical variables were entered

after coding as dummy effects and the total number of original predictors was 21. Three predictors, Alg 30, Perceived Difficulty of Alg 30 Exams., and Hours Spent on Homework in Mathematics, were identified as significant predictors of CR. In this analysis, only one of the two dummy effects for the Difficulty of Alg 30 entered the regression equation. Another analysis was done in which both the dummy effects were entered. These three variables accounted for 58.96% of the variance in CR. These results are provided in Table 2.

Insert Table 2 About here.

In another regression analysis, Alg 30 was dropped as a predictor and then the predictor set constituted only the subjects' perceptions and demographic variables as predictors. Much like the previous regression analysis, if only one of the dummy vectors of a categorical variable entered the regression, then another analysis was made in which all the vectors of that variable were entered. Four variables, whether had taken Geo-Trig in High School, particular First-Year Mathematics Course Enrolled, Hours Spent on Math Homework, and the Extent to which Enjoyed Mathematics in High School, accounted for 48.82% of the variance in CR. Details of these results are given in Table 2. As a comparison, it should be noted that in the previous analysis Alg 30 alone accounted for slightly more than what is accounted for by the non-cognitive variables. Even though these non-cognitive

variables predict a substantial amount of variance, the cognitive correlates are more potent. However, on top of the cognitive variables' predictive efficiency, the non-cognitive variables do add substantially to the prediction.

The Perceptions Regarding High School Mathematics Learning Experiences

The results on only those perceptual items on which there were significant sex differences are given in this section. On the question "Which kind of mathematical material did you find easier to work with and understand?" there were two options: a) word problems, and b) straight mathematical computations. While 16.7% of the males reported that word problems were easier to work with, only 2.7% of the females reported this to be the case. This significant difference ($p \leq .10$) is consistent with the observed differences on achievement tests involving word problems reported in the literature.

Results of the males and females responses to the question "To what extent do you agree that some fields of study/work are more suited for men than women and vice versa?" are given in Table 3. Males and females are significantly different on this item [χ^2 (4) = 19.45, $p \leq .10$]. Males seem to manifest a typical stereotype while females tend to defy it.

Insert Table 3 About here.

Results of the responses to the question "To what extent do your parents/family members feel that some fields of study/work are more appropriate for women than for men and vice versa?" are provided in Table 4. Similar to the responses of males and females to the previous question, males perceive their parents or family members exhibiting a stereotypical bias in terms of the appropriateness of the fields of study or work for men and women [χ^2 (4) = 12.01, $p \leq .10$].

Insert Table 4 About here.

To the question "To what extent do you agree that the study of mathematics is a more appropriate area for men than for women?" males and females responded significantly differently [χ^2 (2) = 14.90, $p \leq .10$]. Although respondents had five response options, only four of the male respondents had used the first two. Therefore, for the chi-square analysis responses to these two categories were combined with a third category. However, results of males and females, given in Table 5, are as observed. These results are similar to those reported for the previous two questions.

Insert Table 5 About here.

Males and females spent respectively an average of 3.91 and 5.09 hours per week on mathematics homework. This

difference was significant [t (98) = -1.83, $p \leq .10$]. On the other hand the average amount of time males and females watched television per week was the same, 13.1 hours. The average mark on Alg 30 for males and females was respectively 83.5 and 81.1, and there was no reliable difference between the two means. So it seems that even though females spent on average significantly more time on mathematics homework their observed achievement was not significantly different or better. In fact, the observed trend was in favor of males.

Discussion

In the post-secondary population of first-year students who have almost similar exposure to mathematics courses, males in general achieved higher than females. This finding is consistent with Benbow and Stanley's (1983) conclusion with regard to a large sex difference in mathematical reasoning ability among intellectually talented preadolescents. In their article, a response to Pallas and Alexander (1983), they ruled out the differential course-taking hypothesis for their population as a plausible explanation and left the situation among the average-ability students open for further investigation. The university population is not strictly an average ability population; nor is it a necessarily a talented population. In the province in which the university is situated, from which the students were selected for the present study, only about 15% of the high school graduates attend university.

Besides the general sex-difference on the Calculus

Readiness Test, it was found that on the components of this test males achieved significantly higher than females on Geometry, Inequalities, and Conceptual Problems. These results extend further the evidence reported for grade 10 students on specific components of the STEP (Randhawa & Hunt, 1987) and of the Canadian Tests of Basic Skills (Randhawa, 1988; Randhawa & Randhawa, 1989b). It appears that components involving logical reasoning such as those in the present study and those reported by Randhawa and Hunt (1987), Exercise Ingenuity or Higher Mental Processes, are critical in sex-related differences in mathematics.

The fact that high school algebra grade, the perceived difficulty of examinations in this course, and hours of homework were significant predictors of CR clarifies the picture of sex differences in that, besides doing well in a cognitive correlate of mathematical achievement, how one perceives the difficulty of summative assessment and the time spent on the work are important factors. Furthermore, the alternate regression results, those observed without using Alg 30 as a predictor variable, suggest that the course enrolled in at the university, geo-trig exposure in high school, enjoyment of high school mathematics, and homework hours are significant predictors. This set of results connects the autonomous learning behavior theory as a plausible explanation of sex-linked differences. People achieve not only because they spend much time but also because there is a purpose to what they are doing and they derive pleasure from doing that

activity. This is further corroborated from the evidence that in spite of the fact that females spent more time on mathematics homework, they did not achieve better than males on Alg 30. Some of the purposive appropriateness and perhaps pleasure components were not as much in evidence for females but they felt they must work hard in order to meet the requirement for requirement sake.

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Table 1

Observed and Adjusted Means on the Calculus Readiness Test Component Scores by Sex

	Observed Means		Adjusted Means	
CR Component	Males	Females	Males	Females
Geometry	2.28	1.87	2.24*	1.91
Inequalities	1.24	0.87	1.21*	0.90
Algebra	3.12	3.23	3.05	3.29
Exponential and Logarithm	4.82	4.54	4.73	4.63
Functions	2.20	1.87	2.15	1.92
Trigonometry	2.08	1.69	2.04	1.74
Conceptual Problems	2.71	2.03	2.65*	2.09

* Males' mean was significantly greater than the females' at the level of confidence of 0.90.

Table 2

Regression Analysis of CR Total Scores on Cognitive and Non-Cognitive Variables

Variable Entered	Obtained R^2	Regression D.F.	Residual D.F.	F-Ratio
Alg 30	.497	1	88	87.07
Perceived Difficulty of Alg 30 Exams	.552	3	86	35.36
Hours Spent on Math Homework	.590	4	85	30.53
Geo-Trig in High School	.215	1	89	24.31
First Year Math Course Enrolled	.356	4	86	11.88
Hours Spent on Math Homework	.450	5	85	13.89
Extent to Which Enjoyed Math in High School	.488	6	84	13.35

Table 3

Percentage of Males (N=55) and Females (N=45) Responding to the Various Options of the Question "To What Extent Do You Agree that Some Fields of Study/Work are more Suited for Men than for Women and Vice Versa?"

Response Category	Males	Females
Strongly Agree	12.7	0.0
Agree	34.5	13.3
Neutral	27.3	22.2
Disagree	14.5	31.1
Strongly Disagree	10.9	33.3

Table 4

Percentage of Males (N=55) and Females (N=44) Responding to the Various Options of the Question "To What Extent Do Your Parents/Family Members Feel that Some Fields of Study/Work are More Appropriate for Women than for Men and Vice Versa?"

Response Category	Males	Females
Strongly Agree	7.3	0.0
Agree	32.7	20.5
Neutral	41.8	34.1
Disagree	14.5	27.3
Strongly Disagree	3.6	18.2

Table 5

Percentage of Males (N=55) and Females (N=44) Responding to the Various Options of the Question "To What Extent Do You Agree that the Study of Mathematics is a More Appropriate Area for Men than for Women ?"

Response Category	Males	Females
Strongly Agree	1.8	0.0
Agree	5.5	0.0
Neutral	34.5	11.4
Disagree	23.6	13.6
Strongly Disagree	34.5	75.0